April, 1943 AIC-5

# INFORMATION SHEET ON COMPRESSION OF DEHYDRATED FRUITS AND VEGETABLES

Western Regional Research Laboratory, Albany, California
Bureau of Agricultural and Industrial Chemistry
Agricultural Research Administration
U. S. Department of Agriculture

In addition to the saving in shipping space that results when foods are dehydrated, further saving can be achieved by compression. When a ship is loaded with cargo at the rate of one ton per 40 cubic feet, the holds are filled and at the same time the ship carries a full load. The objective in the compression of dehydrated foods should therefore be 55 to 60 pounds per cubic foot as the block density. This calculated objective takes into account the fact that the finished package is a little less dense than in unpackaged cakes. Investigations have shown that such densities can be attained without loss of quality in the reconstituted product.

Even higher densities are to be preferred if an oxygen-sensitive product is compressed and packaged in a hermetically sealed container. Dehydrated cabbage, carrots, and tomato juice cocktail are examples. The denser the pack, the lower will be the ratio of oxygen in the can to the dry fruit or vegetable.

A further advantage of compression is the diminished tonnage of steel and tin required when cans are used, since doubling the density halves the metal required. The percentage of saving in cans resulting from compression is numerically equal to the percentage of reduction in bulk. (See table, column 9).

In addition to increased density rehydration to original size and shape is an objective, with a low percentage of fines or small particles. In tests at the Western Regional Research Laboratory fines that pass through an 8-mesh screen after rehydration have been kept under 5 percent. Weighed samples of blocks were rehydrated and screen analyses made of the cooked product. The low percentage of fines prevents a mushy texture and maintains palatability equal to that of unpressed, rehydrated products. The table shows the conditions under which fruits and vegetables have been compressed with 5 percent or less of fines. The time required for rehydration is not increased over that required for unpressed foods.

High densities in the pressed block require higher pressure when the dried fruits and vegetables are low in moisture content. Furthermore, with low moisture content any given pressure will produce a higher density and a more cohesive block if the dried product is hot instead of cold. The densities shown in the table were measured on disks 1/2 to 3/4 inch thick. These disks were kept in cans without wrapping while they cooled, with the exception of onions and carrots, beets, and rutabagas, which were pressed into one-pound blocks 2-1/4 inches thick and were cooled in a holding press. With onions, beets, rutabagas and carrots, it has been found that blocks tightly wrapped in cellophane, with the wrapping sealed, need not be kept in a press to cool. During the cooling the densities under such conditions decrease from 61 to 59 pounds per cubic foot for onions and from 62 to 58 pounds for carrots.

Sun-dried apricots, cut and pitted, can be compressed by hand at room temperature to a bulk density of 42 pounds per cubic foot. A pressure of 150 pounds per square inch at room temperature resulted in a block density of 79 pounds per cubic foot. Higher pressures and an elevated temperature are required for high densities when fruit products are dehydrated to as low as 2 or 3 percent moisture content. The table shows data on apple nuggets for which, because of a 2 percent moisture content, a pressure of 450 pounds per square inch and a temperature of 170°F. were required to produce a block density of 64 pounds per cubic foot. At 75°F., 850 pounds of pressure was required to produce a density of 53 pounds per cubic foot.

For the K rations used in the Army, fruit bars with 20 percent moisture and containing glucose are made by extrusion from machines of the sausage-making type on a belt where the bars are cut to length. These machines use a worm screw to force the fruit paste through a tapered nozzle. Determination of a suitable taper for a particular product requires some experimentation. The bars are wrapped after cutting. If they are to be pasteurized, a suitable wrapping consists of a layer of grease-proof paper for use in handling, a cellophane bag that is heat-sealed after insertion of the bar, and a light chipboard box. A typical pasteurized fruit bar packaged in this manner has a density of 80 pounds per cubic foot.

The maximum attainable density of dried fruits and vegetables can be estimated from (1) existing analytical data on their pulps and (2) data on the densities of their constituents. For dried peaches the estimated attainable density is about 75 pounds per cubic foot at 20 percent moisture content, or 85 pounds if free from moisture.

## Presses and Processes

Hydraulic presses have been used in Germany for the compression of mixed vegetables, herbs, carrots, cabbage, and dried sauerkraut. Continuous tile presses are reported to be in use, in which pressure is imparted by two cams acting at different stations in the machine. Knuckle-joint presses are used in the United States to compress hops, and screw presses are in use for compressing dehydrated egg powder. Some free-flowing powdered soups have been smoothly handled in industrial tableting machines on an experimental basis. The latter are not well suited for use in forming blocks of dehydrated vegetables because: (1) the vegetables are not free-flowing, and therefore automatic and uniform charging of the molds cannot be accomplished in typical machines; and (2) such tableting machines ordinarily operate at compression ratios of 2 to 1, or less. The compression ratio is the ratio of the volumes of the filled mold before and after compression. It can be computed by dividing the density after compression by that before compression. Column 7 in the table shows such ratios. Press makers must know the compression ratio in order to determine the length of stroke of the ram.

The capacity of a press is usually stated in terms of the total safe working pressure between the platens. Molds may have one cavity or multiple cavities. Dried fruits and vegetables have been formed into 6 x 3 x 1-inch blocks.

Blocks 2-1/4 inches thick have been formed and a brick approximately 6-1/2 x 4-1/2 x 2-1/4 inches with one edge rounded has been proposed, since it lends itself well to packing in standard 5-gallon cans at the rate of 16 blocks per can. Such a block will weigh 2 pounds and can be reconstituted into 50 servings of carrots. Military recipes are in terms of 100 servings for companies and probably the most suitable blocks should contain weights corresponding to this number of servings. Blocks can also be formed with indented scorings like those on milk chocolate slabs to facilitate breaking the blocks into smaller units of known appropriate weights.

To reduce friction, the surfaces of molds must be very smooth, a condition which can be produced by a surface grinder. It is frequently the practice to follow this by nickel or chromium plating and polishing. The surfaces of new dies must be lubricated with salt-free, moisture-free, edible oils or fats such as commercial hardened shortenings or special edible lubricants. Continuous use of lubricants may be required to reduce the friction as the fruit or vegetable moves by the plunger past the sides of the mold. Friction resulting from unpolished, inadequately lubricated steel surfaces diverts part of the pressure from the foodstuff to the sides of the mold; thus the effective pressure is decreased at the bottom of the mold, and poor cohesion and a laminated, leafy brick may result.

Sometimes very fine, dried materials or even powder are compressed. Examples are soup mixtures and dehydrated tomato juice cocktail. Most dry powders flow readily and uniformly and such conditions are essential in the automatic feeding of presses. Dehydrated soup powders have been processed satisfactorily on industrial tablet compressing machines. Dried tomato juice of 4 percent moisture content has been readily compressed hydraulically by 1500 pounds per square inch at room temperature to a density of 60 pounds per cubic foot. The cakes were reconstituted to a 6.5 percent juice simply by beating with an egg beater and then adding boiling water and heating one minute. The dry compressed cakes crush easily.

Dehydrated vegetables of diced, sliced, stripped or flake form yield high-density blocks that readily rehydrate and in which the content of fines is low. Hydraulic presses have been used in obtaining the results shown in the tables. The maximum pressure has been maintained for a period, or "dwell," of one minute. Blocking has been effected ordinarily at temperatures from 140° to 160°F. The purpose of an elevated temperature is to produce a pliable state of the vegetable for compression so that it will reach a high density without breaking into small pieces to any considerable extent. Firm blocks of somewhat lower densities have also been produced at ram speeds of 1 to 2 inches per second followed by a "dwell" of 15 seconds.

Fine material passing an 8-mesh screen, caused by compression under the conditions shown in the tabulation, did not exceed 5 percent of the rehydrated vegetables for any form of beets or carrots, or for onions or rutabagas. In general, the cohesion of the blocks was only fair at lower pressures and the same temperatures as those listed in the table. Higher pressures were not required for good cohesion nor were they necessary for adequate compression.

A slight expansion of blocks one-half inch thick occurs in that dimension when they are removed from the hot molds. This expansion is slight because these pieces cool rapidly. An estimate of the time required for cooling thick blocks of carrots in air is afforded by these test data: A 2-1/2 x 1-3/8 x 6-3/4-inch block of compressed, diced carrots cooled at the center from 140° to 90°F. in 3 hours, with air at 80°F. The block was cellophane wrapped, confined in a holding press, exposing the narrow sides and ends only. Removed at 90°F., it held its shape.

Two-pound blocks of diced carrots were formed in a mold 6-11/32 inches x 4-3/8 inches of a suitable depth. The conditions were 160°F., 1200 pounds per square inch and a 30 second period at that pressure. The blocks were removed, wrapped in paper and cellophane and sealed. After compression the dimensions over the wrapping were 6-17/32 x 4-1/2 x 2-3/16 inches. The expansion in a direction perpendicular to the movement of the ram was 5/32 inches on a 6-1/2 inch length, allowing for the thicknesses of paper and cellophane. The immediate expansion parallel to the movement of the ram was 3/8 to 1/2 inch. An additional expansion resulted before it was stopped by the wrap and by air cooling. Holding presses prevent the latter expansion.

Actual practice will be a compromise between the goal of most desirable density, on the one hand, and, on the other, the obtainable equipment and its economic adaptation to use.

Blocks should be wrapped and sealed at once in Kraft paper or cellophane. If the packing case is large enough to permit slight swelling of the blocks, they may be packed, but if very close adherence to the dimensions of the mold is required, the blocks must be cooled under light pressure part way to room temperature.

If compression is carried out with the wrapper inserted in the mold, complete cohesion of the block is not required. With this latter method of compression and wrapping, the wrapper must maintain its integrity as a moisture-vapor resistant sheet without tears, pinholes, or other breaks.

## Holding Presses

The use of holding presses for the purpose of fixing the shape and dimensions of tobacco plugs and blocks of dried hops, catnip, and sage is well known. The time required for tobacco is 5 days; for hops, 12 hours. Such holding presses are not heavy or expensive, because little pressure is used. In one form a hardwood frame of rectangular shape is used. It has a solid bottom end and a loose top end. Plugs are stacked in it nearly to the top; the loaded frame is placed under a small screw press, the top pressed down, wedges are inserted above the top and against the top of the frame, and then the pressure is released and the loaded frame is removed. This type of press, with spaced blocks for ventilation, is one suggested way to cool under pressure.

COMPRESSION OF DEHYDRATED FRUITS AND VEGETABLES
(Tests conducted at the Western Regional Research Laboratory)

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Densities 1/ | | | | | | |
| Fruit or Vegetable | Moisture | Temperature of pressing | Pressure for blocking | Initial | After compression | Compression ratio | Approximate contents of packages | Reduction in bulk 2/ | Equivalent fresh prepared | Dehydrated food for 10 servings 3/ |
| | Pct. | ° F. | Lbs. per sq.in. | Lbs.per cu.ft. | Lbs. per cu.ft. | To 1 | Lbs. per 5 gals. | Pct. | Lbs. per cu.ft. block | (Lbs.) |
| Apple nuggets | 2 | 170 | 450 | 12.5 | 64 | 5.1 | 12.0 | 71 | 620 | 3.5 |
| Apple nuggets | 2 | 75 | 850 | 12.5 | 53 | 4.2 | 12.0 | 64 | 510 | 3.5 |
| Apricot halves | 25 | 75 | 150 | 42.0 | 79 | 1.9 | 28.0 | 44 | 400 | --- |
| Beet cubes | 4.1 | 160 | 650 | 25.0 | 62 | 2.5 | 17.0 | 57 | 740 | 3.5 |
| Beet slices | 5.7 | 120 | 650 | 12.5 | 64 | 5.1 | 8.0 | 80 | 760 | 3.5 |
| Beet strips | 4.2 | 120 | 650 | 15.0 | 57 | 3.8 | 10.0 | 72 | 680 | 3.5 |
| Carrot cubes | 5.2 | 160 | 650 | 19.0 | 62 | 3.3 | 17.5 | 50 | 620 | 4.0 |
| Carrot slices | 4.8 | 160 | 650 | 6.0 | 56 | 9.3 | 8.0 | 75 | 560 | 4.0 |
| Carrot strips | 3.7 | 160 | 650 | 10.5 | 47 | 4.5 | 10.0 | 62 | 470 | 4.0 |
| Onion flakes | 3.0 | 140 | 650 | 6.0 | 61 | 10.1 | 12.0 | 60 | 610 | 2.0 |
| Prunes, whole | 28.0 | 75 | 150 | 48.0 | 78 | 1.6 | 36.0 | 27 | 300 | --- |
| Rutabaga slices 4/ | 6.9 | 140 | 850 | 11.0 | 59 | 5.4 | 12.5 | 68 | 620 | 4.0 |
| Tomatos, spray-dried juice 5/ | 4.0 | 78 | 1500 | 30.0 | 60 | 2.0 | 27.0 | 29 | 670 | 2.0 |

1/ Densities before compression were measured on shaken but unpressed material (Col. 5). Densities of commercial shipments are frequently higher.

2/ The percent reduction in bulk equals the difference between the weights of a 5-gallon can of compressed vegetables and the corresponding weight of the uncompressed vegetable divided by the former weight. In computing the net weights of packages of the compressed foods, allowance is made for 15 percent of unused space in cans and for 5 percent in cartons.

3/ From the War Dept. Tentative Training Manual 10-406, "Dehydrated Foods Cooking Manual", except for figure on tomato juice cocktail, which was obtained from a producer's estimate.

4/ The tentative moisture content of rutabagas is 5 percent, at which blocking will produce a lower density than that found.

5/ Spray dried tomato juice cocktail is packed 4 pounds per No. 10 (3 qt.) can.

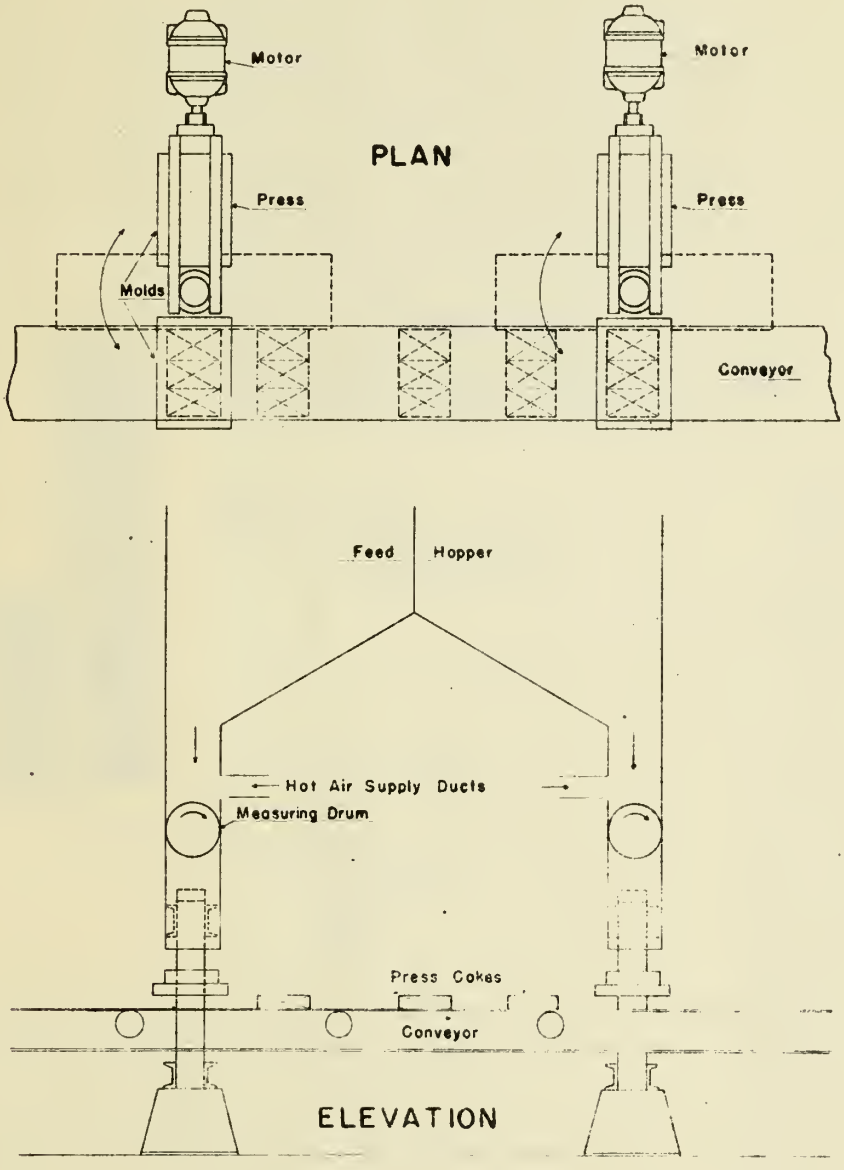


DIAGRAM OF A PACKAGING PRESS